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Research Article

Actual and Potential Land Productivity of Some Soils of Sohag-Red Sea Road Sides, Eastern Desert, Egypt

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ABSTRACT
Egyptian Government focuses on development projects especially in new lands such as Sohag-Red Sea road to improve tourism and agricultural activities. This study aims to assess the actual and potential land productivity. Seventeen soil profiles were chosen depending on the six mapping units of the study area. Soil profiles were drilled and soil samples were collected from each horizon. Nine land characteristics were measured/estimated *viz*. soil moisture content (H), drainage (D), depth (P), texture (T), soluble salts content (S), average nutrient content (N), organic matter content (O), cationic exchange capacity (A) and reserves weatherable minerals (M). Soil samples were analyzed for their mentioned parameters using the standard methods of soil analysis. Accordingly, land productivity (PI) and potentiality (P`I) indices were calculated for all studied soil profiles. The results revealed that actual land productivity of the studied area is extremely poor and can be enhanced 17 times by improving soil moisture content, texture, and organic matter content as the most important controlling-factors. Actual and potential land productivity maps were generated using Arc GIS 10.1 software. These results may help decision-makers for new lands reclamation planning and better agricultural production.
Keywords: *Land productivity, soil mapping, Sohag-Red Sea Road.*

INTRODUCTION

With the rapid population growth and urban sprawl, the soils of the Nile River valley and delta start to lose their fertility and productivity (Mustafa and Negim 2016). Therefore, the Egyptian Government focused on horizontal expansion for reclaiming new lands for increasing agricultural production and reducing the pressure on the existing agricultural land (FAO 2006). Moreover, the golden triangle project which covers a very wide area in the Eastern Desert is one of the most important reclamation programs (NGage 2016). For that, the role of soil researchers appears to provide the necessary information and data to initiate the reclamation of such lands and for developing proper soil management practices and land-use planning (Denton *et al.* 2017). The low-fertility desert lands represent most of Egypt's area, distributed in the east and west Nile Valley. The soils of the Eastern desert are neutral to alkaline, calcareous with a coarse texture and ranging from non-saline to strong-saline soils. Organic carbon content is low (Ibrahim and Ali 2009). The potentiality of GIS for assessing land productivity is important for better land resource management and enhancing land productivity (Ibrahim et al., 2017). This study aims to evaluate the current land productivity status of some soils of Sohag-Red Sea road-sides and also estimate the potential land productivity after the improvement of land productivity parameters.

MATERIALS AND METHODS

Site description

The study site is a part of the Sohag-Red Sea road in the area of Wadi Qena in the Eastern Desert. This area lies between the 26^{o}.65, 26^{o}.75 latitudes (N) and 32^{o}.7, 32^{o}.9 longitudes (E) with an area of ≈204 km^2. The area under investigation is located between the Nile Valley in the West and the Red Sea mountains in the East. The location map of the studied area and soil profiles' locations is shown in figure (1). Wadi Qena is covered with Quaternary deposits which are consisting of gravels, sands, and cemented by fine clay materials (El-Shamy 1988). Wadi Qena catchment is a typical arid basin, which is characterized by an extremely arid climate. The geological map is shown in figure (2). The annual rainfall ranges between 2.75 and 50 mm, while heavy showers are recorded occasionally during winter causing flash floods. The minimum temperature is ranging between 5ºC and 14ºC and the maximum temperature is ranging between 28ºC and 42ºC. The relative humidity (RH) ranges between 30% and 56%. The maximum monthly evapotranspiration is 23.5 mm during June, while the minimum value is 3.1 mm during December (Awad 2008). Prevailing winds are dominantly from the northwest to the southeast with an

average maximum speed of 10 knots/h. The natural vegetation is sparse and distributed randomly over the area. Moringa, Wild Caper, and Salvadoroprisca are the common natural vegetation in the area. Furthermore, agricultural activities are very limited in the area (El-Zawahry *et al.* 2004). The area under investigation is represented by six mapping units i.e., Wadi-Floor (WF), Low-elevated Sand Sheet (LSS), High-elevated Sand Sheet (HSS), Bajada (B), Piedmont (P), and Table Land (TL).

Field-work

Seventeen soil profiles were selected according to the grid system for sampling, and mapping units of the studied area. Latitudes and longitudes for each soil profile were defined by using GPS "Garmin–eTrix" under the WGS84 coordinate system. A detailed morphological description for all soil profiles was noted based on FAO (2006).

Soil analysis

Soil moisture content, drainage, and soil depth were estimated using the in situ descriptions of soil profiles. Soil samples were air-dried, grounded, and 2mm sieved. Particle size distribution was determined by the international pipette method (Jackson 1969). Electrical conductivity (EC) was determined in 1:1 soil-water extract using EC-meter (Jackson 1973). Organic matter contents were determined using the wet-oxidation method (Walkley and Black, 1934). Cation Exchange Capacity (CEC) was determined by sodium acetate (pH≈8.5) and exchangeable cations by ammonium acetate (pH≈7.0) methods (Black 1982). Exchangeable Ca^{+2} and Mg^{+2} were determined using the EDTA titration method, Na^{+1} and K^{+1} were determined using a flame photometer. The base saturation percentage was calculated as a ratio of the measured basic exchangeable cations and CEC.

Estimation of actual and potential land productivity

The actual and potential productivity indices were computed by adopting the procedure of (Riquier *et al.,* 1970). In this method, nine factors were considered for determining soil productivity, soil moisture content (H), drainage (D), depth (P), texture (T), soluble salts content (S), average nutrient content (N), organic matter content (O), soil cationic exchange capacity (A) and reserves of weatherable minerals (M). Each factor was rated on a scale from 0 to 100 and the actual percentages were multiplied by each other to calculate the productivity index (PI) as expressed in (Equation.1).

$$PI = H\times D\times P\times T\times S\times A\times N\times M\times O. \qquad (1)$$

The resultant index for productivity, also lying between 0 and 100, was set against a scale placing the soil in one or other of five productivity classes, namely excellent, good, average, poor, and extremely poor.

The potentiality index (P˴I) was calculated as expressed by (Equation.2) after improving characterizations which considered as limitations of productivity. Then the coefficient of improvement of land productivity (P˴I /PI) was estimated (Equation.3).

$$P'I = H\times D\times P\times T\times S\times A\times N\times M\times O+10\%. \qquad (2)$$

$$P'I / PI = \text{Potentiality Index / Productivity Index}. \qquad (3)$$

Mapping of land productivity

Actual and potential land productivity maps were generated using the IDW-interpolation tool in Arc GIS 10.1 software (ESRI, 2012).

RESULTS AND DISCUSSION

Soil profiles' characterization

The geo-coordinates of soil profiles' locations as well as elevation values were collected using GPS and recorded in decimal degree format. These values were used for mapping with the utility of corresponding soil attributes' data of each soil profile. Soil morphological parameters such as soil moisture content, soil drainage, and soil profile's depth were described and estimated in situ. Table (1) shows the characterization of soil profiles for all land productivity parameters. From the obtained data, it was observed that all mapping units and their representative soil profiles having a soil moisture content in the rooting zone below wilting point around 9 months of the year. These soils are well-drained and deep (more than 120 cm depth). The soils of the area under investigation are coarse-textured which sand content is high. Soil texture of WF and B units are sandy loam while the sand texture is dominant in other mapping units. The total soluble salts in these soils were ranged from low to moderate (0.36% to 0.56%) with an average of 0.49%, while soil organic matter content was low and ranged from 0.14% to 0.40% with an average of 0.24%. The cationic exchange capacity of these soils were ranged from 1.92 to 6.10 cmole(p^+).kg^{-1} with an average of 3.50 cmole(p^+).kg^{-1}. The minimum and maximum values of base saturation were 79.60% and 95.80%, respectively with a mean value of 86.77%.

Actual land productivity evaluation

Soil moisture content could be categorized as H2c and take a value of 40, which moisture is below wilting point around 9 months of the year. Soil depth, soil drainage, and average nutrient content were categorized as P6, D4, and N5, respectively then each of them was given a value of 100. Soil texture has T2b class and rated with a value of 10 whereas; coarse-textured soil (more than 45 percent sand) is there. Regarding soil soluble salts, all soil profiles are under the S3 category (50), except one profile in the HSS unit, and other in the TL unit where having S2 class (70). The content of organic matter in these soils is low (O1) whereas; less than 1% and rated with a value of 85. The soils of the studied area have cationic exchange capacity less than 5 meq/100g soil (A0) for all soil profiles except profiles number (1, 3, 10, and 13) which have CEC more than 5 and less than 20 meq/100g soil (A1). The A0 and A1 classes were rated with values of 85 and 90, respectively

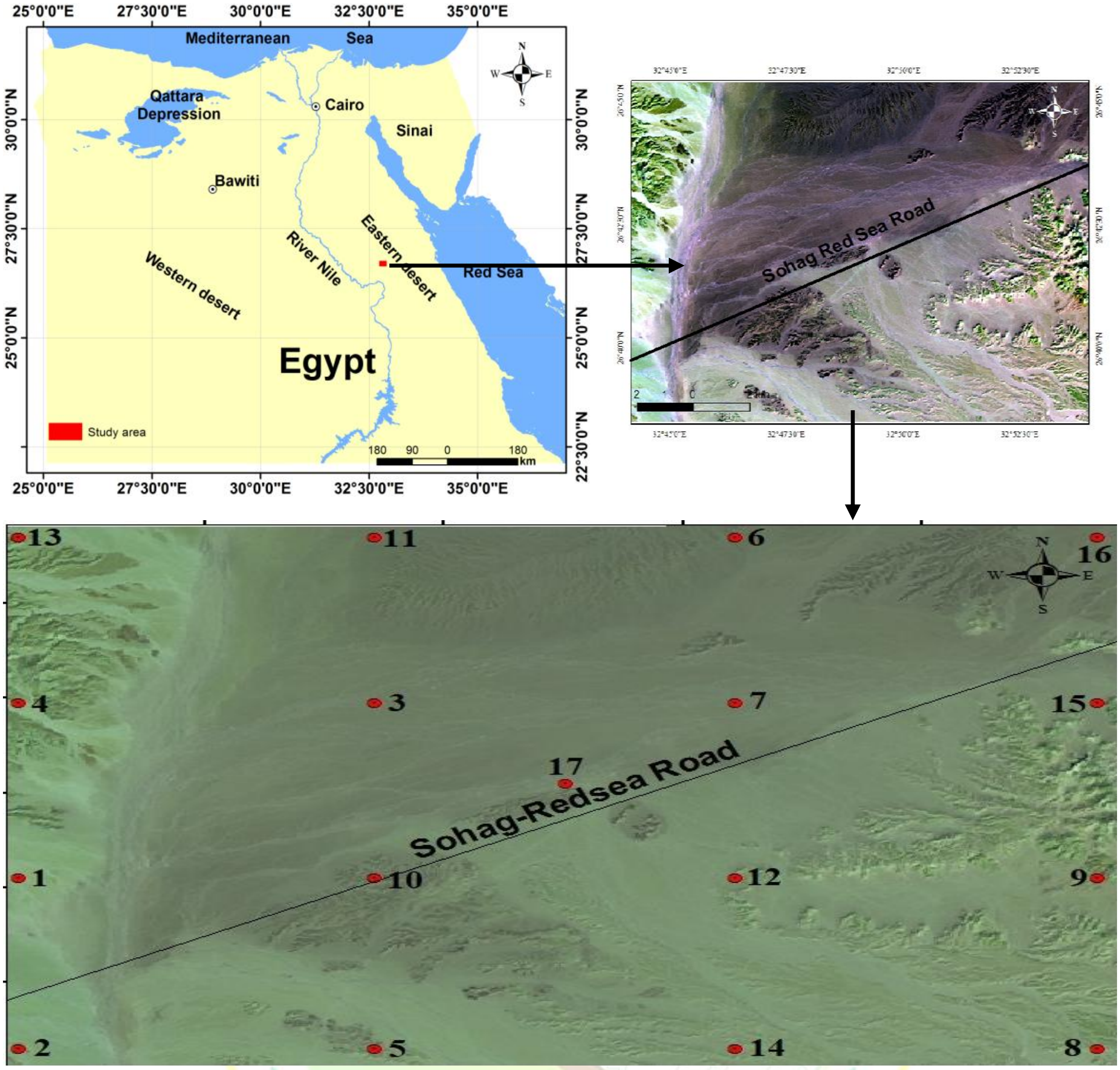


Fig.1: Location map of the studied area and soil profiles' locations.

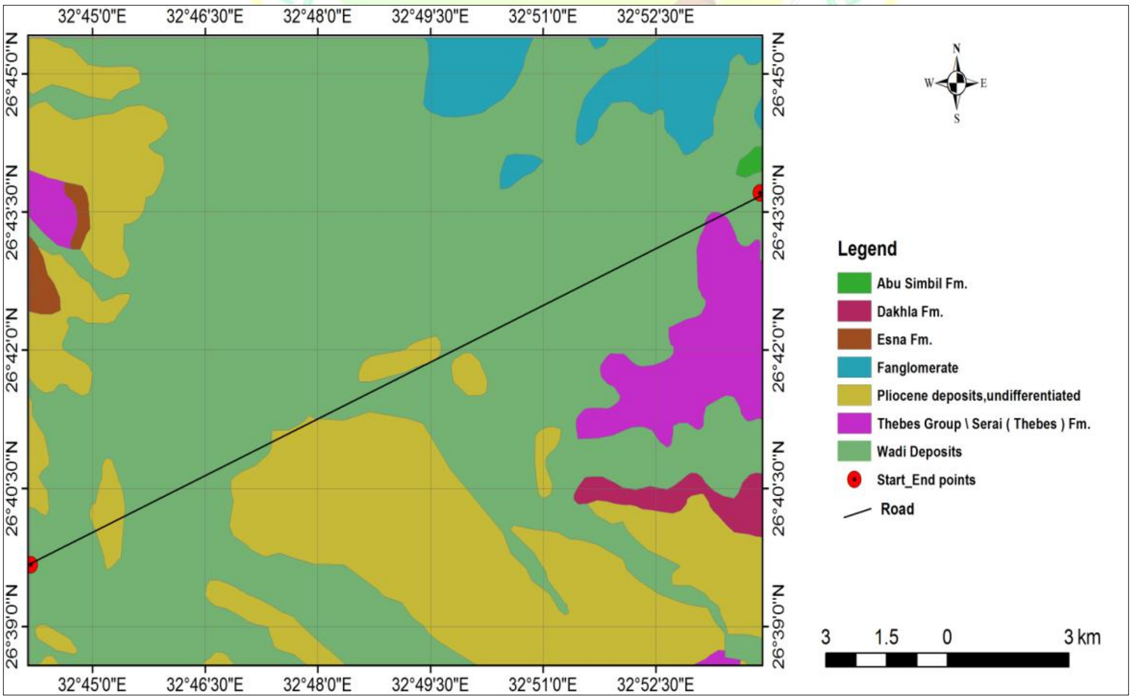


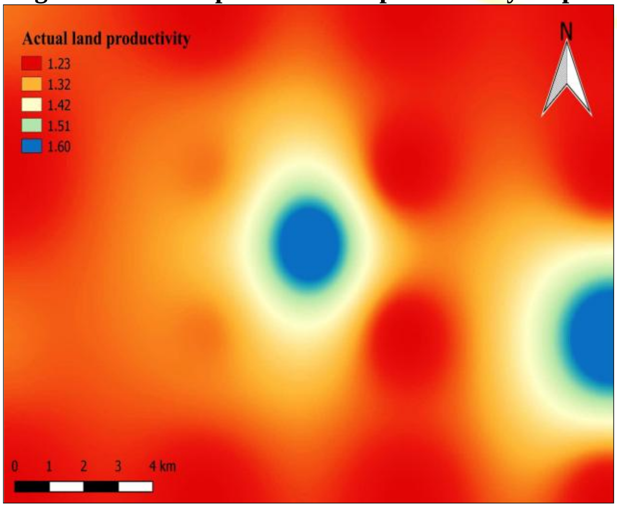
Fig.2: Geological map of the study area.

Table 1: Characterization of soil profiles of the studied area.

Profile No.	Mapping unit	Longitude	Latitude	H	D	P	T	S	O	M	A	N
1	Wadi Floor (WF)	32.738	26.682	<5	Well	130+	LS	0.44	0.34	Very Low	6.10	84.80
2		32.738	26.646	<5	Well	120+	S	0.56	0.29	Very Low	4.30	92.90
3		32.790	26.719	<5	Well	120+	LS	0.46	0.31	Very Low	5.29	85.42
4	Low-elevated Sand Sheet (LSS)	32.738	26.719	<5	Well	130+	S	0.55	0.20	Very Low	2.88	80.66
5		32.790	26.646	<5	Well	130+	S	0.45	0.30	Very Low	2.13	87.53
6		32.843	26.754	<5	Well	125+	LS	0.48	0.27	Very Low	2.44	82.54
7		32.843	26.719	<5	Well	120+	S	0.52	0.33	Very Low	2.51	84.36
8	High-elevated sand Sheet (HSS)	32.896	26.646	<5	Well	120+	S	0.52	0.14	Very Low	2.30	91.33
9		32.896	26.682	<5	Well	120+	S	0.39	0.18	Very Low	1.92	89.80
10	Bajada (B)	32.790	26.682	<5	Well	110+	LS	0.53	0.29	Very Low	5.48	95.80
11		32.790	26.754	<5	Well	120+	LS	0.57	0.19	Very Low	3.23	88.95
12		32.843	26.682	<5	Well	125+	LS	0.53	0.22	Very Low	4.24	86.91
13	Piedmont (P)	32.738	26.754	<5	Well	130+	LS	0.51	0.40	Very Low	5.38	79.60
14		32.843	26.646	<5	Well	130+	S	0.49	0.14	Very Low	2.88	88.23
15		32.896	26.719	<5	Well	120+	LS	0.49	0.20	Very Low	3.28	87.87
16	Table Land (TL)	32.896	26.754	<5	Well	130+	S	0.52	0.16	Very Low	2.58	87.50
17		32.818	26.702	<5	Well	130+	S	0.36	0.16	Very Low	2.48	80.90

H: Moisture Content (%), D: Soil Drainage, P: Soil Depth (cm), T: Soil Texture Grade, S: Total soluble salts (%), O: Soil organic matter (%), M: Reserves of weatherable minerals, A: Cationic exchange capacity, and N: Average nutrient content/Base saturation.

Fig.3: Actual and potential land productivity maps of the studied area.



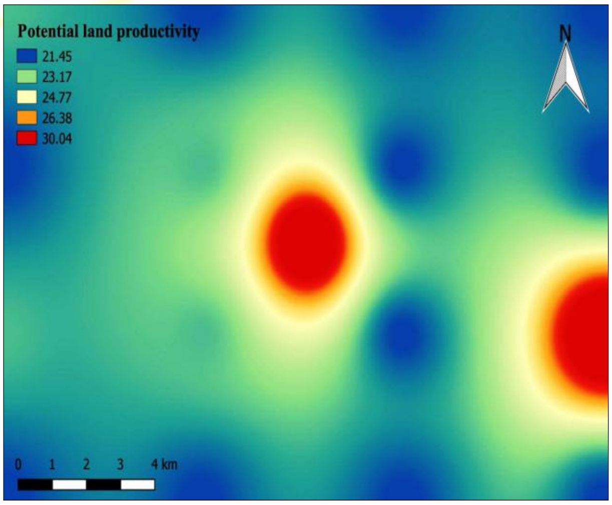


Table 2: Actual land productivity parameters.

Profile No.	Mapping unit	H	D	P	T	S	O	M	A	N	PI
1	Wadi Floor (WF)	H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A1 (90)	N5 (100)	PI5 (1.30)
2		H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A0 (85)	N5 (100)	P5 (1.23)
3		H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A1 (90)	N5 (100)	PI5 (1.30)
4	Low-elevated Sand Sheet (LSS)	H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A0 (85)	N5 (100)	PI5 (1.23)
5		H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A0 (85)	N5 (100)	PI5 (1.23)
6		H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A0 (85)	N5 (100)	PI5 (1.23)
7		H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A0 (85)	N5 (100)	PI5 (1.23)
8	High-elevated sand Sheet (HSS)	H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A0 (85)	N5 (100)	PI5 (1.23)
9		H2c (40)	D4 (100)	P6 (100)	T2b (10)	S2 (70)	O1 (85)	M1 (85)	A0 (85)	N5 (100)	PI5 (1.72)
10	Bajada (B)	H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A1 (90)	N5 (100)	PI5 (1.30)
11		H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A0 (85)	N5 (100)	PI5 (1.23)
12		H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A0 (85)	N5 (100)	PI5 (1.23)
13	Piedmont (P)	H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A1 (90)	N5 (100)	PI5 (1.30)
14		H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A0 (85)	N5 (100)	PI5 (1.23)
15		H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A0 (85)	N5 (100)	PI5 (1.23)
16	Table Land (TL)	H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A0 (85)	N5 (100)	PI5 (1.23)
17		H2c (40)	D4 (100)	P6 (100)	T2b (10)	S2 (70)	O1 (85)	M1 (85)	A0 (85)	N5 (100)	PI5 (1.72)

H2c: Soil moisture (H) in rooting zone below wilting point around 9 months of the year, D4: Well-drained soil with a deep water table (hydromorphic horizon at over 120 cm depth) and no water-logging of the soil profile, P6: Very deep soil with over 120 cm depth, T2b: Soil texture and structure of root zone which extremely coarse-textured soil (more than 45 percent sand), S2: Total soluble salts between 0.2 to 0.4 percent, S3: Total soluble salts between 0.4 to 0.6 percent, O1: Soil organic matter in A1 horizon which less than one percent, M1: Reserves of weatherable minerals in B horizon very low to Nil, A0: Cationic exchange capacity in B horizon less than 5 meq/100g, A1: Cationic exchange capacity in B horizon less than 20 meq/100g, N5: Average nutrient content in A horizon whereas base saturation over 75 percent, and PI5: Land productivity is extremely poor to Nil.

Table 3: Potential land productivity parameters after improvement.

Profile No.	Mapping unit	H	D	P	T	S	O	M	A	N	P`I
1	Wadi Floor (WF)	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A1 (90)	N5 (100)	P`I3 (22.72)
2		H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P`I3 (21.46)
3		H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A1 (90)	N5 (100)	P`I3 (22.72)
4	Low-elevated Sand Sheet (LSS)	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P`I3 (21.46)
5		H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P`I3 (21.46)
6		H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P`I3 (21.46)
7		H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P`I3 (21.46)
8	High-elevated sand Sheet (HSS)	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P`I3 (21.46)
9		H4c (90)	D4 (100)	P6 (100)	T6a (60)	S2 (70)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P`I3 (30.04)
10	Bajada (B)	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A1 (90)	N5 (100)	P`I3 (22.72)
11		H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P`I3 (21.46)
12		H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P`I3 (21.46)
13	Piedmont (P)	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A1 (90)	N5 (100)	P`I3 (22.72)
14		H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P`I3 (21.46)
15		H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P`I3 (21.46)
16	Table Land (TL)	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P`I3 (21.46)
17		H4c (90)	D4 (100)	P6 (100)	T6a (60)	S2 (70)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P`I3 (30.04)

H4c: Soil moisture content (H) when rooting zone below wilting point for 3 months and wet below field capacity for over 6 months of the year, T6a: texture and structure of root zone when dominant texture grades are heavy sandy loam, sandy clay, clay loam, silty clay loam, or silt, O3: Soil organic matter in A1 horizon is averaged from 2 to 5 percent, and P`I3: Land potential productivity after improvement which under average productivity class.

The productivity index was calculated for each soil profile and it is obvious that all soil profiles have extreme poor to nil land productivity (PI between 0 and 7). All related data are shown in table (2).

Improvement of land productivity parameters

From the previous results, the limitations of these soils for land productivity are soil moisture content (H), Soil texture (T), and soil organic matter (O). These parameters can be enhanced to increase land productivity. Therefore, these soils shall be irrigated using the supplementary methods of irrigation such as sprinkler irrigation. This process will increase the rate of soil moisture parameter from H2c to H4c which is given 90 as the rating. The surface layer (0-25 cm) of these soils can be mixed with heavy textured soil which transported from other agricultural lands. The addition of organic materials and nutrients application of manure, crop rotation also improvement of humic conditions will improve soil texture. These practices may enhance texture from T2b to T6a (from 10 to 60). After the improvement of organic matter, it can be increased from O1 to O3 (85 to 100). By improvement of organic matter, 10% will add to the final Index. The data of land productivity parameters after improvement are shown in table (3).

Potential land productivity evaluation

The data of land productivity parameters after improvement were used to calculate land potential productivity (P`I) which ranged from 21.46 to 30.04. These soils were found to be average in potential productivity. The coefficient of improvement of the studied area (P`I/PI) was calculated and its value was 17.48. It means that productivity can be multiplied by more than 17 times with the application of all suitable management techniques.

Mapping of actual and potential land productivity

The IDW-Interpolation tool in Arc GIS 10.1 software was used for generating actual and potential land productivity maps as shown in figure (3). These maps show that the Central and Eastern parts of the studied area have better productivity compared to rest areas. Land productivity increased after the improvement of land productivity parameters.

The soils of the studied area have low moisture content. These soils are well-drained, deep, and coarse-textured. Soil organic matter content is low while total soluble salts are ranged from low to moderate. Moreover, CEC is low and BS is more than 75%. The actual land productivity index showed that these soils are extremely poor in productivity. Some practices and land management processes should be followed to improve land productivity. The limitations in these soils are soil moisture content, soil texture, and soil organic matter. The potential land productivity can be increased 17 times after improvement. The integration of soil surveying, sampling, laboratory analysis, and GIS technique found to be an effective tool for producing spatial information as well as land productivity data. These data can be utilized for better land use management, planning for new lands reclamation, and enhancing agricultural productivity.

REFERENCES

Awad A. 2008. Integration of remote sensing, geophysics, and GIS to evaluate groundwater potentiality: A case study in Sohag region, Egypt. *The 3rd International Conference on Water Resources and Arid Environments and the 1st Arab Water Forum*.

Black C A. 1982. *Methods of soil analysis-Part2, chemical, and microbiological properties*. Agronomy series no. 9, ASA, SSSA, Madison, Wis., USA.

Denton O A, Modupe V O, Ojo AO, Adeoyolanu O D, Are KS, Adelana AO, Oyedele AO, Adetayo AO, and Oke A O. 2017. Assessment of spatial variability and mapping of soil properties for sustainable agricultural production using geographic information system techniques (GIS). *Soil & crop sciences* **3**(1):279-366.

El-Shamy I Z. 1988. Quantitative geomorphometry and surface runoff control for Wadi Qena, Eastern Desert. E.G.S. *Proceedings of the 6th Ann. Meeting*, pp.13-26.

El-Zawahry A E, El-Gamal M H, and Emam Y. 2004. Developing renewable groundwater resources in arid lands pilot case: The Eastern Desert of Egypt. *Hydrological modeling tasks* **3:**29-32.

ESRI. (2012). Arc Map version 10.1 User Manual. ESRI, 380 New York Street, Redlands, California, 92373-8100, USA.

FAO. 2006. *Guidelines for soil description* (4th ed.), FAO, Rome, 95p.

Ibrahim M M, Wahab M A, Ali R R, EL-Baroudy A A and Hussein A A. 2017. Physiographic and soil mapping of Qena and El-Qarn Wadis by using remote sensing and GIS. *Egyptian Journal of Soil Science* **57**(2):137-141.

Ibrahim M S and Ali M H M. 2009. Total iron and manganese status and availability under various land use. *Australian Journal of Basic and Applied Sciences* **3**(2):698-705.

Jackson M L. 1969. *Soil chemical analysis-advanced course*. 2nd edition published by the author, Dept. of Soil Sci., Univ. of Wisconsin, Madison, USA.

Jackson M L. 1973. *Soil chemical analysis*. Prentice-Hall of India Private Limited, New Delhi, India.

Mustafa A A and Negim O E. 2016. Utilizing of geo-informatics for mapping land use/land cover changes in Sohag, Egypt. *American Journal of Environmental Engineering and Science* **3**(1):33-42.

NGage consulting. 2016. Growing business through the regulation-Golden triangle. Public strategy and Government relation specialists. S.A.E.

Riquier J, Luis Bramao D, and Cornet J P. 1970. *A new system of soil appraisal in terms of actual and potential productivity (first approximation).* Soil resources, development, and conservation service, land, and water development Division. FAO.

Walkley A and Black I A. 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil science* **37**:29-38.